Pacific Northwest Salmon

PINK • CHUM • CHINOOK • COHO • SOCKEYE

INTRODUCTION

This article describes the biology, history and development of Pacific Northwest salmon and their fisheries, and identifies issues of special concern that have caused some of the salmon stocks to be listed under the Endangered Species Act. The status of Pacific coast salmon stocks are described in Unit 12; Alaska salmon stocks are considered in Unit 13.

Salmon have played an important role in the culture and commerce of the Pacific Northwest since time immemorial. Six species are traditionally called Pacific salmon: Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), and the cherry or masou salmon (*O. masou*). All but the Asian cherry salmon are found in the northeast Pacific Ocean and spawn in rivers of the Pacific Northwest. All Pacific salmon spawn only once in their lives, and all species are considered to be anadromous, i.e., they migrate from saltwater to freshwater to spawn. The catch history for each species is shown in Figures 7 to 11.

Pink Salmon

The pink salmon has the smallest body size of all North American Pacific salmon, averaging 1.0 to 2.5 kg at maturity. Pink salmon are sometimes called “humpback” salmon or “humpies” because the males develop a large dorsal hump at maturity. It is the most abundant species of Pacific salmon and the least dependent on freshwater. Thus, depending on whether Pacific salmon evolved from a freshwater or marine ancestor, pink salmon may be considered either the most primitive or the most highly evolved species.

Pink salmon commonly spawn around the north Pacific Rim from North Korea to Puget Sound, Washington. Spawning has been reported as far south as Monterey Bay, California, but the southernmost runs regularly occur in Puget Sound. Most pink salmon spawn in the lower sections of coastal rivers and creeks, though some spawn in brackish water. The young salmon or fry migrate to sea immediately after emerging from their gravel beds and, during extensive offshore North Pacific migrations, grow to full size and return to spawn at age 2.

Because of this rigid two-year life cycle, populations that spawn in even years and odd years are reproductively isolated even if they spawn in the same stream. In fact, odd-year pink salmon in North America are more closely related to odd-year pink salmon in Asia than to even-year pink salmon that spawn in the same North American streams. In Puget Sound and southern British Columbia, most pink salmon spawn in odd years.

Chum Salmon

Chum salmon, also called dog salmon, is the second most abundant and the second largest Pacific salmon at maturity, averaging 4.6 kg. Like pink salmon, chum salmon spend little time in freshwater. Most adults enter freshwater when they are fully mature and spawn and die within a few days of freshwater entry. Also like pink salmon, chum salmon usually spawn in the lower reaches of rivers and rarely ascend streams above any barriers that require leaping, although some in the Yukon River (Alaska/Canada) migrate over 2,000 km upstream to spawn. Chum salmon juveniles also migrate to sea immediately after emerging from the gravel and undertake extensive oceanic migrations. However, unlike pink salmon, chum salmon do not always mature at the same age: a few mature at age 2, some at age 3, but in the Pacific Northwest, most mature at age 4.

Chinook Salmon

Chinook or king salmon is the least abundant species of Pacific Northwest salmon and has the largest body size at maturity, with fish as large as 57 kg (126 lb). The species has two distinct life history patterns which are characterized as “stream-type” or “ocean-type” rearing.

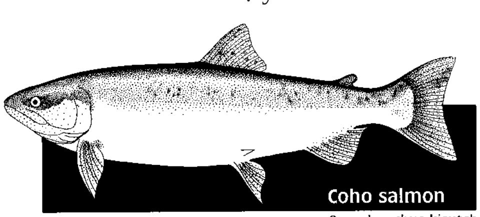
Adult stream-type chinook salmon tend to enter freshwater in the spring or summer when they are still bright silver in color and not fully mature. They typically migrate to headwater areas and hold in pools until the fall when they spawn. Juveniles predominantly remain in freshwater for one or more years before migrating to the sea. At sea, the stream-type chinooks make extensive high-seas migrations.

Ocean-type chinook salmon tend to spawn in the larger mainstem rivers at lower elevations than stream-type fish. Adults generally enter freshwater in the fall and spawn within a month or two of freshwater entry. Ocean-type juveniles rear in freshwater or estuaries for a few months after emergence from the gravel and then migrate to sea as subyearlings. At sea they tend to remain in the area of the continental shelf where they are more vulnerable to shore-based fisheries.

Because of the great differences in their life histories, freshwater habitat has a much larger influence on the survival of stream-type chinook salmon than on that of ocean-type chinook salmon. Stream-type chinook salmon are also less suitable for hatchery rearing because the extended freshwater holding periods of both adults and juveniles require extensive facilities. Consequently, stream-type fish, which was once the dominant life-history type in Washington, Oregon, and California, has declined far more than ocean-type chinook salmon in the region.

Coho Salmon

Coho salmon has a less diverse life history than chinook salmon, and it is more dependent on freshwater habitat than ocean-type chinooks. In the southern part of its range, juveniles spend their first year in freshwater before migrating to sea. In more northerly areas, they may spend 2 years in freshwater. Like ocean-type chinook, coho salmon tend to remain relatively close to shore, where they are harvested in commercial and recreational troll fisheries.


Coho salmon
Oncorhynchus kisutch

A small percentage of the fish, mostly males, return to spawn at age 2 after spending one summer in the ocean, but the majority of coho mature at age 3. Coho salmon tends to spawn in the headwater areas of streams that are smaller than those used by chinook salmon, and coho juveniles rear for their first year in backwaters and side channels before migrating to sea as yearlings. Erosion and sedimentation resulting from logging has degraded much of the coho salmon spawning habitat, and channelization of coastal streams for agriculture and flood control has severely reduced the available rearing habitat of coho salmon in many areas.

Sockeye Salmon

Sockeye salmon has the most complex life history of North American Pacific salmon. The species usually spawns in river systems that contain lakes. Runs of sockeye salmon in a single river system can include separate races that spawn upstream and downstream from a lake, as well as beach spawners that spawn within the lake itself. There are also resident populations of sockeye, known as kokanee, that never migrate to sea.

After hatching and emerging from the gravel, sockeye fry migrate to lake waters where they live from 1 to 3 years before migrating to sea. The fish mature after spending from 1 to 5 years in the ocean.

At maturity, the male sockeye salmon develops a pronounced dorsal hump and an exaggerated hooked jaw, and both sexes turn bright red with a green head. In North America, the sockeye salmon is the third most abundant Pacific salmon species, after pink and chum salmon. However, the sockeye salmon is the least abundant salmon species in the Pacific Northwest, as its largest populations are found in Canada and Alaska.

History

Salmon played a central role in the culture of Indian tribes of the Pacific Northwest prior to the arrival of Europeans. Its abundance, as well as that of other fish and game, permitted a human population density that was unequaled elsewhere in North America. The reliability of runs and the relative ease of capture of migrating salmon permitted a degree of affluence among tribes of the Pacific Northwest, which is amply reflected in their art, commerce, and culture.

The early Indians used hook and line, traps, weirs, jigs, spears, and a variety of nets to harvest salmon. Large river systems like the Sacramento, Columbia, and Fraser had many salmon runs returning at different times. Consequently, salmon were available for harvest nearly year round.

Within Puget Sound, the coastal Salish people developed a fishing method called reef netting that targeted Fraser River sockeye salmon on their homeward migration. This method involved guiding the migrating salmon over a net suspended between two canoes and then raising the net. Reef netting was labor-intensive but highly productive, and is still in limited use today.

In 1855 and 1856, the U.S. Government negotiated treaties with native tribes in the Pacific Northwest when land was opened for new settlement. In these treaties, Indians were guaranteed the right “to fish in common” at their traditional fishing locations with the non-native settlers.

When the early Europeans arrived on the west coast of North America, they also began to harvest salmon for subsistence and limited commerce at local markets as fresh fish and for export as salted and dried fish. In 1864, the Hume brothers started a salmon cannery on the Sacramento River in California. Three years later, they opened their first cannery on the Columbia River, and the commercial salmon fishery rapidly expanded.

Early canning production focused entirely on chinook salmon. Chinook catches peaked on the Columbia River in 1883 when 630,000 cases of salmon, representing nearly 20,000 t of fish, were packed. The salmon were caught in freshwater with weirs, traps, fish wheels, seines, and gillnets. As the chinook runs began to decline, the industry also targeted other Pacific salmon species. Total harvest peaked in 1911 when about 22,500 t of salmon were taken from the Columbia River. Nearly every accessible river in California, Oregon, and Washington with a significant run of salmon had at least one cannery on it.

In Puget Sound, the canning industry targeted sockeye salmon from the Fraser River in Canada. Salmon migration routes brought a significant portion of Fraser River fish through U.S. waters in the San Juan Islands and in the waters off Point Roberts at the U.S.-Canada border. The canneries initially obtained a large part of their fish from the Indian reef-net fishery, but as more efficient gear was introduced, the Indians were almost completely displaced from the commercial fishery.

In the 1890s, traditional reef-net sites were taken over by fish traps, which were often owned by the canneries and were much more efficient than the traditional Indian gear. Gillnetters and purse seiners began to harvest fish before they reached the traps. When boats became motorized in the early part of the 20th century, they were able to fish the runs as they entered the Strait of Juan de Fuca, and to follow the runs through Puget Sound.

At that time, the Indians lacked the financial resources necessary to enter these capital-intensive fisheries and mostly were restricted to subsistence fishing near river mouths on reservation land. In the early-1900s, concern arose over declining salmon abundance, and the states began to restrict salmon fishing seasons. The ocean troll fishery rapidly expanded thereafter for a number of reasons: the introduction of powerboats made the offshore fishery feasible, gear was relatively inexpensive, and the fishery was initially exempt from license requirements and closed seasons because it operated outside state jurisdiction.

With the additional gear types and participants, salmon runs continued to decline. States began to pass further restrictions on fishing, but many restrictions were aimed more at allocation than at conservation.

In the 1930s, Washington and Oregon banned fixed gear, such as fishwheels and traps, for salmon. Most fishwheels and traps were owned by canneries, and the less efficient gillnet and recreational fisheries had more public support than the cannery operators. Since then, there has been a trend to eliminate more efficient gear types and to allow expansion of effort in the remaining fisheries. California eliminated all non-tribal salmon gillnetting in the 1950s, and Oregon did the same in state coastal rivers. Presently, the only legal gear in the ocean salmon fisheries is hook and line, but gillnetting is still permitted in the Columbia River and by Indian tribes in estuaries and fresh water. Purse seining, gillnetting, and reef netting are all permitted in Puget Sound.

In 1974, a federal court presided over by Judge George Boldt ruled that the treaty phrase “to fish in common” entitled the treaty tribes to half of the available harvest from salmon stocks that passed through traditional Indian fishing grounds. The State of Washington had argued that when it had become a state, its authority to manage fisheries and commerce within its boundaries superseded Indian treaties negotiated by the federal government when Washington was a territory. The Court also ruled that tribal fishing rights had precedence over any other salmon fishing privileges that all others had.

The Boldt decision mandated reallocation of a major portion of the salmon resource and thus a subsequent downsizing of the non-Indian commercial fishery. Since 1974, treaty tribes in the Pacific Northwest have been allocated an increasing share of the salmon resource and have assumed a significant role in management of the stocks.

As Pacific Coast settlement progressed, freshwater salmon habitat has been lost. In California, sedimentation caused by hydraulic mining in the mid-1800s nearly extirpated salmon runs in the American, Feather, and Trinity Rivers. Throughout California, Oregon, and Washington, logging, flood control projects, and diversion of water for agriculture reduced the amount of available habitat and degraded much of what was left. On the Fraser River in British Columbia, rockslides and debris from railroad construction caused a blockage of the river at Hells Gate that prevented most fish passage in 1914 and contributed to the decline of upper Fraser River populations. From the early-1900s through the 1960s, construction of dams for hydropower, irrigation, and flood control continued to progressively block fish passage and reduce salmon habitat despite requirements that the larger dam projects include construction and operation of hatcheries as mitigation for their impacts on salmon.

Present Fisheries

Recreational

Currently, recreational salmon fisheries operate in freshwater, saltwater, and in estuaries: all are restricted to hook-and-line gear and target primarily chinook and coho salmon. Recreational fisheries in state waters are managed by the states, while those in the ocean are managed by the Pacific Fishery Management Council.

In the ocean and Puget Sound, anglers fish from private skiffs and commercial passenger fishing vessels by either trolling or drifting with bait. In California, most fish taken in the ocean recreational fishery are chinook salmon. In Oregon and Washington, coho salmon are usually targeted, but in all three states, both species are taken whenever regulations allow. Within Puget Sound, some pink salmon are taken by trolling in the recreational fishery, and a chum salmon fishery has developed in recent years that is primarily catch-and-release using light tackle or flies. In freshwater, most recreational fishing is done from boats or river banks using light tackle.

Commercial

Non-tribal commercial fisheries remain offshore, in Puget Sound, and in the Columbia River. In the ocean, all fish are taken by trolling with hook-and-line. A commercial salmon troller typically uses 6 wire lines with up to 6 “spreads” or pieces of terminal gear on each line for a total of 36 lures fishing simultaneously. In recent years, ocean regulations have been adopted restricting the number of spreads on each line in an effort to make the commercial fisheries more selective. Commercial troll fisheries target chinook and coho salmon, though they take a few pink salmon incidentally.

Most troll catches are marketed as premium fresh or frozen products, as the fish taken in saltwater are bright silver and unmarked by nets. In Puget Sound, commercial fishing is conducted with gillnets and purse seines, in addition to troll gear. The fleets target Fraser River sockeye and pink salmon runs, which tend to school during their return migration, making them more vulnerable to net gear. Some also target hatchery-reared coho salmon runs that have earlier run timing than the natural spawning populations of coho. They also take large numbers of Puget Sound pink salmon in odd years and any other salmon that are encountered.

Tribal

In Puget Sound and off coastal Washington, many treaty tribes engage in commercial, ceremonial, and subsistence salmon fishing. Tribal commercial fisheries use the same gear types as non-tribal commercial fisheries, and, though primarily commercial, some fish are kept for personal use. Tribes also operate fisheries in estuaries and in freshwater, targeting salmon and steelhead (the sea-run form of rainbow trout). The majority of these fisheries use gillnets, although dip nets and weirs also still are used. As a general rule, fish taken in freshwater are used for subsistence and ceremonial purposes, though harvest in excess of subsistence needs is often sold.

In the Puget Sound area and on the coast of Washington, many treaty tribes participate in the fishery management process through the Northwest Indian Fisheries Commission. On the Columbia River four treaty tribes belong to the Columbia River Inter-Tribal Fish Commission. The decline and loss of many upper Columbia River salmon stocks have made it difficult for upriver tribes to receive their allotted share of the harvest.

In California, three tribes fish the Klamath River basin: The Yuroks harvest salmon in the Klamath River estuary with gillnets, the Hoopa Valley Tribe operates a subsistence gillnet fishery in the Trinity River (a Klamath tributary), and the Karuks have a subsistence dipnet fishery at Ishi Pishi falls on the mainstem Klamath River. These tribes differ from the treaty tribes of Washington and Oregon in that no treaty was ever negotiated with the U.S. Government that guaranteed them perpetual fishing rights.

Management

Pacific salmon management involves several national and international jurisdictions. In 1955, the International North Pacific Fish Commission (INPFC) was established by convention by the United States, Japan, and Canada to develop agreements for harvesting and conserving Pacific salmon on the high seas. INPFC sponsored extensive research programs to determine ocean distribution and migration pathways of all species of Pacific salmon and made recommendations on high-seas salmon fishing. Research sponsored by the INPFC included pioneering work on tagging, scale pattern analysis, genetic stock identification, and parasite analysis. The organization was dissolved in 1993 and its obligation was assumed by the North Pacific Anadromous Fish Commission (NPAFC). The NPAFC has four members: the three original INPFC nations and Russia.

The International Pacific Salmon Fisheries Commission was established in 1936 by treaty between the U.S. and Canada to allocate harvest of Fraser River fish and to restore stocks of sockeye and pink salmon in the Fraser River. In 1985, this organization was replaced by the Pacific Salmon Commission (PSC) as established by the U.S.-Canada Pacific Salmon Treaty. The PSC, through its Fraser River Panel, manages sockeye and pink salmon fisheries in treaty waters and allocates harvest as jointly agreed. The PSC also has the authority for in-season regulation of salmon fisheries within treaty areas based on information collected during the season.

In Washington, Oregon, and California, ocean salmon fisheries are managed by the Pacific Fishery Management Council under a framework management plan. Each year, the Council reviews the status of key stocks and evaluates management recommendations. The Council adopts recommendations for ocean fisheries seasons and submits them to the U.S. Secretary of Commerce for approval. NOAA Fisheries implements ocean fishing regulations and, with Council advice, provides in-season management. States and tribes monitor landings in the commercial and recreational fisheries, but the U.S. Coast Guard and NOAA Fisheries are also involved in enforcement.

Issues of Concern

Allocation

Pacific salmon fisheries are managed to meet annual spawning escapement goals. Each year, a forecast is made for most stocks and, given expected abundance levels and legally mandated tribal allocations, a set of fishery openings and quotas is designed to meet escapement goals for the most critical stocks. Disputes over allocation of harvest have been common between gear types within the commercial fisheries, between commercial and recreational fishing interests, between states, and between tribal and non-tribal fisheries. While most allocation issues are addressed through the management process, disputes over tribal and non-tribal allocation have been negotiated or resolved primarily outside of the management arena, in the courts.

The current fishery management structure operates under the MFCMA which was passed after the 1974 Boldt decision had allocated 50% of the harvest to treaty tribes in Washington. Implementing this allocation has been difficult because most tribal fisheries have traditionally operated in terminal areas (i.e., in rivers and estuaries) making tribal fishermen the last in line to physically harvest salmon. For salmon to reach tribal fisheries, they must first escape all the preterminal fisheries.

Prior to the Boldt decision, preterminal fisheries were harvesting salmon at rates that probably exceeded the harvest rates necessary to achieve the long-term potential yield, and they still have the capacity to overexploit all salmon stocks. To reduce the ocean harvest enough to allow terminal fisheries 50% of the total harvest, pre-terminal fisheries had to reduce fishing by more than 50%. This has required profound reductions in non-tribal fishing fleets.

In Puget Sound, the State of Washington and the tribes have undertaken a number of programs to minimize impacts on preterminal fisheries. Large hatchery programs were developed to increase coho salmon production and the number of fish available for harvest, and fishery openings were provided exclusively for tribal fishing. Hatchery programs have selected broodstocks with early run timing to allow fisheries to target hatchery fish while avoiding naturally produced fish. This policy is also intended to minimize the impacts of hatchery straying on natural populations of coho salmon. In the southern part of Puget Sound and Hood Canal, coho salmon are reared for an extended period in saltwater net-pens prior to release in an attempt to keep fish near terminal areas to enhance recreational and tribal fisheries.

Tribes on the Klamath River in California were not included in the Boldt decision because the Hoopa Valley reservation originally was established by presidential order rather than by treaty. Consequently, there was no treaty language guaranteeing tribal fishing rights on the

Klamath River. California banned gillnetting in freshwater in 1956 and asserted that the state had the authority to regulate fisheries on Indian reservations. It was not until 1979 that a federal court recognized the right of Indians to fish commercially on reservations in the Klamath basin. However, the court decision did not specify tribal allocations.

The lack of agreement over tribal allocations in the Klamath basin has complicated the management of ocean salmon fisheries in southern Oregon and northern California. In 1992, the Yurok tribe argued that because they had surrendered no aboriginal rights by signing a treaty, they were entitled to at least as large a share of the harvest as treaty tribes. In 1993, the U.S. Departments of Commerce and Interior issued a legal opinion supporting the Yurok claim, and ocean salmon fisheries in southern Oregon and northern California have subsequently managed to provide a 50% allocation of Klamath River chinook salmon to the tribes.

Habitat

Habitat degradation and loss is a constant threat to salmon survival and persistence. The impacts generally increase from north to south and have affected each species of Pacific salmon in proportion to its dependence on freshwater habitat. Toward the southern end of the Pacific salmon range, impacts have been the greatest. In California's central valley, which once contained over 6,000 miles of salmon spawning and rearing habitat. Because of dam construction for flood control, hydropower, and irrigation, less than 200 miles of habitat remain today, and the remaining habitat continues to decline in quality. Dams have interrupted the movement of gravel downstream, so as floods wash spawning gravel downstream, it is not replaced by new gravel from upstream. The construction of levees to reduce flooding has also reduced contributions of spawning gravel from stream banks which once resulted from shifts in the river's channel. Bank protection programs have eliminated much of the shaded nearshore habitat where young salmon once reared, and irrigation diversions entrain fish into agricultural fields and canals.

In the coastal rivers of northern California and Oregon, logging and agriculture have had several detrimental impacts on salmon. Logging has increased sedimentation in coastal streams, filling in pools and increasing the proportion of fine sediments in spawning gravel, which can suffocate incubating eggs. Past logging practices did not leave buffer strips of timber along streams to provide shaded habitat and large woody debris. Shaded habitat maintains lower water temperatures and large woody debris plays an important role in pool formation in smaller streams where coho salmon live. In lower portions of coastal streams, river bottoms have been channeled to reclaim the floodplains for agriculture and grazing. This has greatly reduced the meandering of streams which used to produce the side channels and backwater areas utilized by young coho salmon.

In the Columbia River basin, development of hydropower resources has entailed construction of 11 dams on the mainstem Columbia River and several more on the Snake River. Fish passage facilities were provided on most dams for adult fish migrating upstream to spawn, and fish guidance and bypass structures were added to pass downstream migrants around the turbines. However, the fish passage facilities have been less effective than anticipated and are still being refined.

Reservoirs created by hydroelectric dams inundated most mainstem spawning habitat, and impassable dams cut off headwater areas that historically contained many miles of spawning habitat. Impounded reservoirs also created habitat for salmon predators and increased the time that it takes smolts to complete their downstream migration. To improve survival of juvenile fish on their downstream migration, NOAA Fisheries and the U.S. Army Corps of Engineers instituted a transportation program whereby smolts are collected at the upper dams and loaded onto barges for transportation past all downstream reservoirs and dams. While this program has been successful in improving the survival of downstream migrants, the abundance of several upper basin runs of salmon has not increased.

On the Olympic Peninsula of Washington, the headwaters of most rivers lie inside the Olympic National Park, where they are protected and remain in relatively pristine condition. However, the lowlands through which these rivers flow fall outside the park and have been extensively logged with concurrent habitat degradation. Particularly noteworthy is the Elwha River, which was once one of the largest producers of salmon on the Olympic Peninsula. It was unique in that it supported all five species of Pacific salmon, in addition to steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarki*), and the Dolly Varden (*Salvelinus malma*) and bull trout (*S. confluentus*). The chinook salmon produced by the Elwha River were the largest salmonids on the Olympic Peninsula with fish reportedly taken that were over 45 kg.

From 1910 to 1912, a dam was constructed for hydropower 8 km from the mouth of the Elwha, and no provisions were made for fish passage. In 1927, a second impassable dam was constructed 14 km above the first one. Thus, for over 80 years all natural salmon spawning in the Elwha has been restricted to the lower 8 km of the river where the habitat continually has declined owing to interruption of the flow to spawning gravel from the headwaters. In 1992, the U.S. Congress passed the Elwha River Ecosystem and Fisheries Restoration Act with the goal of removing the two dams and fully restoring the Elwha River Ecosystem. The cost of removing the dams has been estimated from $147 to $203 million, with the majority associated with removing and stabilizing accumulated sediments behind the dams.

Puget Sound has also experienced a great deal of habitat modification. The coastal areas were extensively logged, and many coastal forests are being harvested for the second or third time. The area has rapidly become urbanized, and the population is growing faster in many rural areas than it is in the cities. In several rivers, summer flows are reduced due to agricultural diversions, and the flows of other streams are intermittent because of pumping from the aquifers for domestic water supplies. Industrialization and shipping have produced problems with contamination in Puget Sound, which, while usually not directly lethal to salmon, weakens their resistance to disease and their ability to avoid predators. Production of salmon in Puget Sound has been maintained at relatively stable levels through extensive hatchery programs for chinook and coho salmon and through less extensive programs for chum salmon.

Artificial Propagation

Historically, loss of natural salmon production to water development and hydropower projects has been mitigated by hatchery construction. Hatcheries also have been built for fisheries enhancement. The first fish culture facility on the U.S. West Coast was a salmon hatchery on the McCloud River in California, opened in 1872 by the U.S. Commission of Fish and Fisheries. Since then hatcheries have proliferated coastwide. Currently, hatcheries probably account for the majority of chinook and coho salmon production in California, Oregon, Washington, and Idaho, although the ratio of hatchery to natural production has not been estimated on a coastwide basis. Hatcheries initially were viewed as the salvation of salmon stocks and fisheries in the face of habitat destruction and degradation, but they have come under increasing scrutiny in recent years.

Production of natural populations may be depressed through competition with hatchery smolts for food and habitat, and predation of natural fry by larger hatchery smolts. Juvenile hatchery fish often are larger than naturally produced juveniles because of earlier spawn timing and more favorable growing conditions in the hatchery. When huge numbers of hatchery smolts are released into rivers with native fish, they can reduce the availability of prey for the natural fish. The influx of hatchery fish also can disrupt the territorial behavior of naturally produced juveniles, causing them to emigrate prematurely from rearing areas. In addition, coho salmon rear for a year in freshwater before release, and when they are released from the hatcheries, may prey upon naturally produced fry emerging from the gravel.

Hatchery populations also tend to be more productive than naturally spawning populations. Some fisheries in the Columbia River and in Puget Sound are managed for hatchery production. This means that stocks are harvested at rates that natural populations cannot sustain. If natural stocks are subjected to the same harvest rates in mixed-stock fisheries, they will be eliminated. In the mainstem of the lower Columbia River, this has already occurred with coho salmon. In Puget Sound, the Washington Department of Fish and Wildlife has attempted to protect natural stocks by selecting hatchery broodstock with earlier run timing than the natural populations and by timing commercial fisheries in terminal areas to target hatchery stocks. Whether this is sufficient to protect wild populations remains to be seen.

One of the greatest criticisms of hatcheries is the impact they may be having on the genetic structure of natural populations. Hatcheries have been operated by a large number of public agencies as well as a few private organizations, and there has been no comprehensive program to manage the genetic makeup of hatchery stocks.

Several practices in artificial propagation give rise to these criticisms. Over the years, hatchery broodstock and gametes have been transferred over broad geographic areas. There is concern that this movement of fish between hatcheries may have disrupted the genetic structure of natural salmon populations in North America. There is also some evidence that propagation of fish in hatcheries over many generations has resulted in domestication of some stocks, and that fish adapted to an artificial environment are less fit for life in the wild. Thus, when hatchery fish stray from the hatchery and spawn with wild fish they may decrease the fitness of the natural populations. Attempts to minimize interaction between natural and hatchery fish by actively selecting fish with dissimilar life histories means that when hatchery fish do spawn with natural fish, their progeny are even less likely to survive.

A relatively new aspect of artificial propagation is the increasing role of commercial aquaculture. Along the Pacific coast there have been several attempts at ocean ranching, which involves operating a hatchery that releases fish to the wild with the idea of harvesting the mature fish when they return to the hatchery. Most ocean ranching operations have been unsuccessful, but the same model is being used successfully in Alaska for pink salmon enhancement.

A more successful approach has been farming, or net-pen rearing, of salmon. Salmon farming involves rearing the fish entirely in captivity, usually in floating net-pens. The production of farmed salmon on a global scale has been steadily increasing since the late-1970s, and in 1994, global production of farmed salmon exceeded the total commercial fishery production of Alaska. While most farmed salmon are Atlantic salmon (*Salmo salar*), chinook and coho also are raised.

From a market standpoint, farmed salmon have several advantages over salmon harvested in the fisheries: production is predictable and relatively stable, while natural production may fluctuate widely; fresh fish can be supplied year-round, while most wild salmon fisheries are highly seasonal; and fish quality is more consistent than in the commercial catch. As the industry continues to improve domesticated strains of salmon and to develop better feeds, the attractiveness of farmed salmon should continue to increase as its capital cost decreases.

Endangered Species

The Endangered Species Act (ESA) considers a species to be endangered if it is in danger of extinction throughout all or a significant portion of its range and threatened if it is likely to become endangered in the foreseeable future. The ESA also allows listing distinct population segments as unique “species.” Because of declines in a number of individual salmon populations, NOAA Fisheries has received several petitions to list runs of salmon and anadromous trout for protection under the ESA.

Because the ESA does not define the term “distinct population segment,” NOAA Fisheries has developed a policy to define this term for Pacific salmon. According to this formula, a salmon population (or group of populations) can be considered distinct only if it constitutes an evolutionary significant unit (ESU). In order to qualify as an ESU, a population segment must be enough isolated reproductively from other population segments to allow genetic differences to occur, and it must comprise a significant component of the evolutionary legacy of the species as a whole. Currently, Snake River spring/summer chinook salmon are listed as threatened, and Sacramento River winter run chinook salmon, Snake River sockeye salmon, and Snake River fall run chinook salmon have been listed as endangered under the ESA. NOAA Fisheries has proposed listings for Umpqua River coastal cutthroat trout, and

Klamath Mountains Province steelhead trout.

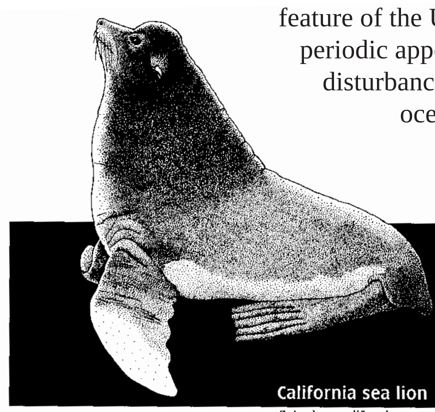
Because of the large number of petitions received, the agency has undertaken coastwide ESA status reviews of all species of Pacific salmonids. The process involves determining the boundaries of the ESUs that comprise each species and the status of each ESU. Completion of these comprehensive status reviews should streamline the process of reviewing future petitions for listing salmon runs under the ESA.

Marine Mammal Interactions

Pacific salmon stocks have had highly publicized interactions with other protected species. Prior to the passage of the MMPA, seals and sea lions were routinely shot by fishermen. Populations of marine mammals were kept at low levels, and their interactions with the fisheries were relatively minor.

The MMPA has been extremely successful in restoring some species, notably the northern elephant seal, the harbor seal, and the California sea lion. Populations of seals and sea lions have increased in some areas to the point where they are now causing problems for fisheries. For several years there have been complaints from the marine commercial and recreational fishing industries that California sea lions have become a substantial source of noncatch mortality associated with ocean fishing.

Sea lions follow fishing boats and wait for fish to be hooked, then prey upon the hooked fish. The rate of sea lion predation on hooked salmon has not been extensively studied, but anecdotal reports suggest that it is substantial. Aggregations of seals and sea lions also have been observed in estuaries and at river mouths where salmon congregate as they begin their upstream migration. The magnitude of the problem has not been studied extensively, but the numbers of marine mammals observed indicate that they potentially may be a large source of salmon mortality.



California sea lion
Zalophus californianus

The most visible example has been at the Ballard Locks on the ship canal near downtown Seattle, Washington. The locks are a popular gathering place for tourists and locals alike, and all salmon and steelhead migrating upstream to Lake Washington must pass through the locks or through the fish ladder located there. In recent years, up to 20 young male California sea lions, collectively named “Hershel,” have congregated at the locks to take advantage of the concentration of salmonids during their spawning migration. Steelhead runs in Lake Washington have declined precipitously in this time, and it has been estimated that the sea lions may be killing as much as two-thirds of the run each year. Attempts to deal with the sea lions have been unsuccessful: loud noises to frighten them away only resulted in sea lions overcoming their fear of loud noises. Several sea lions were trapped and relocated to California, only to return. After extensive review, NOAA Fisheries finally announced plans to use lethal removal as a method of last resort, but there has been tremendous public outcry in defense of the sea lions.

Marine Environment

Pacific salmon spend much of their lives and achieve the vast majority of their growth in the marine environment, yet relatively little is known about how variability in the marine environment affects their growth and survival. However, with improvements in our capability for global data collection and remote sensing, patterns in oceanographic features on larger spatial and temporal scales are emerging.

One well-known environmental feature of the U.S. Pacific coast is the periodic appearance of El Niño, a disturbance in the upper layers of the ocean originating in the eastern tropical Pacific Ocean and producing abnormally warm surface waters off the coasts of California, Oregon, and Washington. This surface warming is associated with reduced upwelling and reduced productivity of coastal waters, and with a corresponding production decline in many fisheries, including those of chinook and coho salmon.

Productivity in the eastern North Pacific now appears to be driven substantially by changes in the entrainment of the North Pacific West Wind Drift Current. This current, which originates as an extension of the Kuroshio Current, approaches the North American continent in the vicinity of the U.S.-Canada border. There the current splits and is diverted southward into the California Current along the U.S. west coast and northward into the Alaska Gyre in the Gulf of Alaska. When more of the West Wind Drift is diverted to the south, the California Current is strengthened. This is associated with colder water and with increased productivity off the west coast of the contiguous United States. When more of the West Wind Drift is entrained into the Alaska Gyre, the California Current is weakened and productivity decreases. At the same time, a strengthened Alaskan Gyre is associated with warmer temperatures and increased productivity in the Gulf of Alaska.

Changes in the entrainment of the West Wind Drift are driven by changes in global atmospheric circulation patterns and seem to occur on decadal scales. Since about 1977, conditions have favored entrainment of the West Wind Drift into the Alaska Gyre most of the time. The changes in productivity associated with this change in ocean currents have affected different salmon species in different ways. All salmon stocks in Alaska have benefited from increased productivity in the Alaska Gyre.

Pacific Northwest sockeye, chum, and pink salmon all migrate far offshore and to the north, and have benefited from increased productivity in the Alaska Gyre. Chinook and coho salmon from California, and Oregon tend to remain in coastal waters, and they have suffered from reduced productivity in the California Current system.

Chinook and coho salmon from the Columbia River northward tend to remain in coastal waters, but migrate still further north. The effects on these stocks have varied depending on the migration pathway and feeding grounds of individual stocks. Chinook salmon from the upper Columbia River tend to migrate far to the north and have maintained their productivity. Coastal stocks of chinook and coho salmon from Washington and northern Oregon and those from Puget Sound also tend to migrate to the north, but not as far as upper Columbia chinook. These stocks have experienced declines in productivity, but not as severe as those of stocks to the south. Attempts to evaluate the effects of any management impacts on Pacific salmon will always be confounded by variability in the marine environment.

Discussion

Salmon fisheries have always been a prominent feature of the cultural heritage of the Pacific Northwest. For thousands of years Northwesterners have identified with the fish, and with the activity of fishing for them. Now the futures of both fisheries and fish seem to be in question.

While salmon fisheries in Puget Sound have maintained their total landings in recent years, non-tribal fisheries have been severely reduced since the Boldt decision. Tribal fisheries have benefited from the Boldt decision and have increased their take from a minor fraction of the landings to a major component. Within Puget Sound, fisheries are presently supported primarily by species that have relatively little dependence on freshwater habitat, on production originating from the Fraser River in Canada, and on hatchery production of chinook and coho salmon.

Non-tribal fisheries in the Pacific Northwest face difficult times. Landings have been reduced recently to protect spawning escapements. Non-tribal commercial fisheries have also seen their share of the harvest decrease as a result of recent changes in allocation. Recent record landings of Alaska salmon and the increasing production of farmed salmon have driven prices down and undermined the toehold that Pacific Northwest commercial fisheries have traditionally maintained in the market. With additional constraints likely to result from recovery efforts for endangered species, the economic viability of these fisheries is doubtful.

The plight of Pacific salmon is particularly compelling because their dependence on freshwater to complete their life cycle has always made them very visible, available, and vulnerable. The challenges they overcome on their spawning migrations are inspiring, yet it is this same dependence on fresh water that currently threatens them. There are still some healthy natural pink and chum salmon populations in the Pacific Northwest, but it is increasingly difficult to find healthy natural populations of species that spend more of their lives in freshwater. The human population in the Pacific Northwest continues to increase, and people are also dependent on fresh water. The challenge we face with preserving these magnificent fish is to protect the needs of the species while accommodating the needs of the people. o

Marine Mammal Protection Act

• Keeping Pace with Wildlife Conservation •

Introduction

When the Secretary of the Interior produced his 1945 report on the "Fishery Resources of the United States," he noted that whale stocks worldwide were at an all time low. In that report, Remington Kellogg reported that the U.S. whaling industry had at one time engaged some 735 vessels and 40,000 people, representing an investment of $40 million and an annual harvest worth $8 million. However, in 1943, this fishery was reduced to only 3 vessels and employed 59 people; capital investment was less than $1 million and the annual harvest worth only $44,000. This dramatic turn was representative of the decline of whaling world wide and largely due to overharvesting.

The next three decades saw increases in some marine mammal populations (e.g., gray whales, humpback whales, California sea lions), while others declined (e.g., Hawaiian monk seals, Steller sea lions). These developments were coincident with the decline of many commercially valuable fisheries resources. In response, scientists and resource managers began to focus their attention on alternatives to traditional single-species conservation regimes. The growing recognition of the need for ecosystem-level resource management was reflected in legislative actions of the 1970s and 1980s, including: the Marine Protection, Research, and Sanctuaries Act; the Coastal Zone Management Act; the National Environmental Policy Act; the Marine Mammal Protection Act; the Endangered Species Act; and the Magnuson Fisheries Conservation and Management Act. In recent years discussion of holistic multispecies management and the sustainable use of renewable resources has included the issue of maintenance of biodiversity. A key concern was the potential effect of resource utilization on the diversity and stability of ecosystems. This is particularly true for marine ecosystems, where community structure has been significantly altered by the depletion of principal prey and predator species.

From its inception in 1972, the Marine Mammal Protection Act (MMPA) has reflected the need for ecosystem-based management in its primary goal—"to maintain the health and stability of marine ecosystems." Three explicit charges are to: 1) maintain animal stocks at optimum sustainable population (OSP) levels as functioning elements of their ecosystems, 2) restore depleted stocks to OSP levels, and 3) reduce incidental mortality and serious injury to "insignificant levels approaching a zero mortality and serious injury rate." The legislative record of the MMPA frequently refers to another implicit goal, which is to minimize interference with commercial fishing enterprises while meeting the other goals.

The MMPA has been reauthorized several times and amended in response to advances in our understanding of marine mammal population dynamics evolving legal, political, and economic landscape surrounding marine wildlife conservation and management. In this regard, the most recent amendments include mandates to undertake studies of the Bering Sea and Gulf of Maine ecosystems, and directs research toward multispecies interactions between pinniped populations and the fisheries. With each reauthorization, however, the fundamental conservation goals of the Act have prevailed.

1994 MMPA Amendments

The most significant recent event affecting the conservation and management of U.S. marine mammals was the enactment on April 30, 1994 of Public Law 103-238, the Marine Mammal Protection Act Amendments of 1994. These amendments supersede the five-year exemption from the MMPA for most commercial fisheries enacted by the 1988 MMPA amendments. During this five-year exemption period NOAA Fisheries developed a regime for the long-term management of marine mammal/fisheries interactions. The regime is based on a scientific rationale for determining how many marine mammals may be incidentally taken; it reflects sound principles of wildlife management; and it is consistent with and implements the intent of the legislative act. Two aspects of the revised MMPA are discussed below: Stock Assessment Reports (SARs), which represent the starting point for evaluating the status of U.S. marine mammals at the beginning of the new regime; and the Potential Biological Removal (PBR), a concept that establishes a quantitative process for setting levels of take such that marine mammal stocks will equilibrate within their optimal population size.

Regional Stock Assessment Reports

The amended MMPA requires the Secretary of Commerce and the Secretary of the Interior to jointly develop SARs for all marine mammal stocks found within waters of U.S. jurisdiction. This does not apply to stocks having a remote possibility of occurring regularly in U.S. waters. The U.S. Fish and Wildlife Service (USFWS) has sole authority for stocks of Pacific walrus, Alaska polar bear, West Indian manatee, and Alaska and California sea otters, while NOAA Fisheries is responsible for the remaining cetaceans and pinnipeds (155 stocks, including 10 eastern tropical Pacific dolphin stocks). SARs are assigned to three separate regions—Alaska, Pacific including Hawaii, and Atlantic including the Gulf of Mexico. Three regional scientific review groups were established to review the SARs and identify areas of uncertainty and research needed to address them. They also advise the Secretaries on issues that affect the conservation of marine mammal stocks and their interactions with the commercial fisheries. The review groups are composed of 10–12 persons with expertise ranging from marine mammal population dynamics and modeling to commercial fishing technologies to represent a balance of regional, conservation and industry expertise, interests, and concerns.

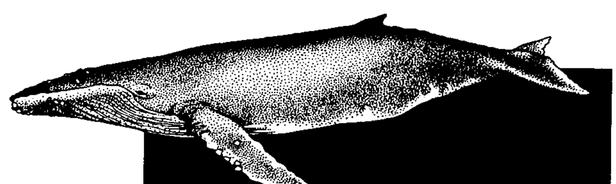
The MMPA requires SARs to include how listed stocks are defined, minimum abundance estimates, current and maximum net productivity rates, current population trends, calculations of PBRs, and assessments of whether incidental fishery takes are “insignificant and approaching zero mortality and serious injury rate.” Additional requirements include an assessment as to whether the level of human-caused mortality and serious injury is likely to reduce the stock to below OSP, or whether the stock should be classified as a “strategic stock.” SARs are to be reviewed annually for “strategic stocks” and for stocks for which new information is available. Stocks not otherwise considered are to be reviewed at least once every three years.

Strategic stocks are those that are listed as endangered or threatened under the ESA, or declining and likely to be listed in the foreseeable future. Strategic stocks also include those designated as depleted under the MMPA (i.e., below OSP), and those for which human-caused mortality exceeds the estimated PBR. When implemented by NOAA Fisheries and USFWS, the new MMPA mangement regime will contribute to the long-term database needed to detect and evaluate trends for all U.S. marine mammal stocks.

The 1994 Amendments require that take reduction teams be formed for each strategic stock and charges these teams with developing a take reduction plan to reduce takes to below the PBR. Plans for strategic stocks must be submitted to the Secretary within six months of the convening of a team. Team membership includes representatives of federal and state agencies, appropriate regional fishery management councils, interstate fisheries commissions, academic and scientific organizations, environmental groups, all commercial and recreational fisheries groups and gear types that impact the stock, Alaska Native organizations or Indian tribal organizations, and others as the Secretary deems appropriate.

The Potential Biological Removal Process

The 1994 MMPA amendments established, for the first time, the fundamental concept for calculating PBRs or sustainable removal levels for marine mammal stocks. Section 117 defines PBR to mean, “the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its OSP. The PBR is the product of the following factors:



Humpback whale

Megaptera novaeangliae

(a) the minimum population estimate of the stock, N_{MIN}.

(b) one-half the maximum theoretical or estimated net productivity rate (R_{MAX}) of the

stock at a small population size.
(c) a recovery factor (F_R) of between 0.1 and 1.0."

NOAA Fisheries interprets the PBR approach as an extension of precautionary resource management. The primary intent is to respond to the greater degree of uncertainty that is associated with assessing and reducing marine mammal mortality from incidental fisheries takes, as compared to mortality from directed harvests.

Advantages of the PBR approach are that it is not based on any particular population model, it allows conservative management to proceed when lacking detailed information, it provides an incentive to improve information on stock size by increasing precision (i.e., lowering coefficients of variation, CVs), it is based on readily measurable quantities, and it focuses on achievable goals.

Recognizing that the authorizing legislation provided only limited guidance for implementing the PBR process, and the need to establish quantitative criteria for calculating PBRs that could be consistently applied across regions, NOAA Fisheries, in consultation with the USFWS and the Marine Mammal Commission, convened a series of workshops and meetings in 1994. Guidelines for calculating PBRs for marine mammal stocks, including quantitative criteria for making those calculations, were developed. Once parameter values for the three PBR elements (N_{MIN}, R_{MAX}, and F_R) were identified, their performance was evaluated using statistical simulations to explore the behavior of hypothetical populations under a range of precision about these input variables. The simulations indicated optimal parameter values that met the MMPA goals of the recovery of depleted stocks, and maintenance of stocks within OSP with 95% probability within 20-100 years (Fig. 12). For example, it was found over a range of abundance estimate CVs, from 0.2 to 0.8, that using the 20th percentile of the abundance estimate for N_{MIN} was sufficient to allow populations to recover to or remain within OSP. This occurred in the absence of problems such as biased estimates of abundance or mortality, while meeting both the 20-year and 100-year criteria. Further simulations called "robustness trials" were undertaken to explore the effects of unknown bias or other problems with input parameter valuess, including underestimation of mortality by as much as 50%. Simulations indicated that a F_R value of 0.50 (for pinnipeds and for cetaceans), in combination with the 20th percentile of the abundance estimate, resulted in all populations equilibrating near OSP within the specified time period.

Minimum Population Estimate

The minimum population estimate (N_{MIN}) is defined in the 1994 MMPA amendments as an estimate of the number of animals in a stock "that:

(a) is based on the best available scientific information on abundance, incorporating the precision and variability associated with such information; and,
(b) provides reasonable assurance that the stock size is equal to or greater than the estimate."

Consistent with these definitions, N_{MIN} is calculated such that a stock of unknown status would achieve and be maintained within OSP with 95% probability. Population simulations demonstrated that this goal can be achieved by defining N_{MIN} as the 20th percentile of a log-normal distribution based on an estimate of stock abundance:

$$N_{MIN} = N/\exp(0.842 * (\ln(1+CV(N)^2))^{1/2})$$

where N is the abundance estimate and CV(N) is the coefficient of variation of the abundance estimate. This is equivalent to the lower limit of a 60% 2-tailed confidence interval.

If abundance estimates are believed to be biased, appropriate correction factors are applied to obtain unbiased estimates of N. In such cases, the coefficient of variation for N includes uncertainty in the estimation of the correction factor. Where direct counts of animals are available, such as for many pinniped stocks, these direct counts are used as the estimate of N_{MIN}. Other approaches can also be used to estimate N_{MIN} provided the same level of assurance that the stock size is equal to or greater than that estimate is maintained.

Maximum Rate of Increase

One-half of the maximum rate of increase (R_{MAX}) is defined in the MMPA as "one-half of the maximum theoretical or estimated 'net productivity rate' of the stock at a small population size." The term "net productivity rate" means "the annual per capita rate of increase in a stock resulting from additions due to reproduction, less losses due to natural mortality."

Consistent with a risk-adverse approach, these default values are near the lower range of measured or the theoretical maximum values that are thought to be plausible for a wide range of species (i.e., 0.12 for pinnipeds and sea otters and 0.04 for cetaceans and manatees). When reliable stock-specific information is available on R_{MAX}, such as an observed rate higher than the default, substitutions for these default values can be made in calculating PBR.

Recovery Factor

The MMPA defines the recovery factor (F_R), as being within the range from 0.1 to 1.0. Adding F_R to the definition of PBR ensures the recovery of populations to their OSP levels. This does not significantly increase the time necessary for endangered, threatened, or depleted populations to recover. Values of F_R less than 1.0 allocate a proportion of expected net production toward population growth and compensates for uncertainties that might prevent population recovery. These may include biases in the estimation of N_{MIN} and R_{MAX}, or errors in the determination of stock structure.

While values for N_{MIN} and R_{MAX} are adopted from strict criteria as starting points for calculating initial PBRs, the value of F_R can be "tuned." Tuning requires that reasonable assurance in the form of scientific justification or other reliable information is employed to ensure that the estimates of abundance, mortality, and R_{MAX} are not severely biased. Further, coefficients of variation of the abundance and mortality estimates must fall within accepted ranges.

Simulation studies demonstrate that to achieve the conservation goal of encouraging the recovery of stocks that are depleted (below OSP), the default F_R for depleted and threatened stocks and stocks of unknown status should be no greater than 0.5. The recovery factor of 0.5 for depleted or threatened stocks, or stocks of unknown status, was determined by the assumption that the coefficient of variation of the mortality estimate is equal to or less than 0.3. If the CV around the mortality estimate is greater than 0.3, the recovery factor must be further decreased to achieve stock recovery to OSP with 95% probability. F_R for stocks listed as endangered is assigned as 0.1.

Stocks known to be within OSP (e.g., as determined from quantitative methods such as dynamic response or back-calculation), stocks of unknown status that are thought to be increasing, or stocks taken primarily by aboriginal subsistence hunters that are not known to be decreasing, can have higher F_R values. These values may be up to and including 1.0, provided that there have been no recent increases in the levels of mortality.

The recovery factor is also used to accom-

Fig.12. PBR Simulations. A sample of 30 cetacean populations simulated for 100 years for 4 different cases. PBR is calculated as the product of N_{MIN}, ½ R_{MAX} (0.02), and F_R (1.0), and is recalculated from a "new" abundance estimate every 4 years. The simulations assume that the entire PBR is taken each year as incidental fisheries mortality. The thick solid line represents a fraction of K (carrying capacity) of 0.5. Populations above that line are within their Optimum Sustainable Population level (OSP), whereas populations below that are considered depleted under the MMPA. Each population starts at a fraction of 0.4 K. The dotted line represents the trajectory of a population with no incidental fisheries mortality. The two panels on the left represent simulations using a best estimate of abundance (or point estimate) for N_{MIN}— the majority of the simulated populations are depleted after 100 years. The two panels on the right represent simulations using the 20th percentile of the abundance estimate for N_{MIN} (the lower 60% 2-tailed confidence limit), representing the strategy for calculating PBR adopted by NOAA Fisheries. In these panels, at least 95% of the simulated populations are within OSP after 100 years. The two upper panels represent simulations where the abundance estimate is relatively imprecise (CV=0.8), and the two lower panels represent simulations where the abundance estimate is relatively precise (CV=0.2).

modate additional information and allow for management discretion as appropriate and consistent with the MMPA goals. For example, if human-caused mortalities include more than 50% females, the recovery factor could be decreased to compensate for the greater impact of this mortality on the population (or increased if the mortalities are less than 50% female). Similarly, declining stocks, especially ones that are threatened or depleted, can be given lower recovery factors; the value of which may depend on the magnitude and duration of the decline.

Alternatively, recovery factors can be increased in some cases. If mortality estimates are known to be relatively unbiased because of high observer coverage, then it may be appropriate to increase the recovery factor to reflect the greater certainty in the estimates. For example, in the case where the observer coverage was 100% and the observed fishery was responsible for virtually all fishery mortality on a particular stock, the recovery factor for a stock of unknown status might be increased from 0.5 to 0.75. This action reflects reduced concern about bias in mortality, but continued concern about biases in other PBR parameters and possible errors in determining stock structure. Recovery factors of 1.0 for stocks of unknown status are reserved for cases where there is assurance that N_{MIN}, R_{MAX}, and the kill are unbiased, and where the stock structure is unequivocal or those cases where the population is not known to be adversely affected by human interactions. Where stocks are not known to be adversely affected by human activities, but whose status is unknown, recovery factors up to 1.0 are appropriate.

Throughout 1994 and the spring of 1995, NOAA scientists identified several opportunities for continuing or new research that would advance and assess the performance of the PBR-based regime for managing takes of marine mammals. NOAA Fisheries published the final versions of the SARs in the summer of 1995 and will conduct follow-up PBR workshops. o